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Exploring Business Students' and Liberal Arts Students' Beliefs about Physics and Physics Learning

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The study describes the extent of change in students' cognitive expectations after going through an Introductory Physics course. Cognitive expectations are beliefs about the learning process and the structure of knowledge. Using the Maryland Physics Expectations (MPEX) survey, the students' responses reflected the highest level of agreement with the 'experts' response' in the following clusters: independence, math link, reality link, and effort link. The study has shown that students could move from a novice-like view of Physics and learning Physics to a more expert-like view.

Key words: cognitive expectations, physics education research, beliefs about Physics

Introduction

Science and technology plays a vital role in modern societies. The past decades have shown us what a scientifically- and technologically-educated population can contribute to a nation's economic and social development. Wright (1999, p.15) asserts that "it is now widely acknowledged that science and technology exerts a profound influence on such diverse areas as our interaction with the physical world; patterns of production and distribution of goods and services; the socio-economic lifestyle of communities; and even the value systems of some nations". An understanding of science and technology can be regarded as one of the most essential pre-requisites for coping with the facts, principles, forces, and practices which shape the world.

The Association of South East Asian Nations (ASEAN) has recognized the importance of promoting science and technology in the region. The UNESCO Science Report (2005) notes that countries in South East Asia have targeted four universal fields: information technology, micro-electronics, new materials, and biotechnology. All four fields are generally regarded as being important in the 21st century. The ASEAN member-countries have realized that they must invest in research and development in these fields in order to acquire the technological capability to make use of advances in the same fields developed in other countries.

The goal for the coming decades, as encapsulated by the ASEAN Vision 2020, is of "a technologically competitive ASEAN, competent in strategic and enabling technologies, with an adequate pool of technologically-qualified and trained manpower, and developing strong networks between science and technology institutions and centers of excellence" (UNESCO, 2005, p.233). To achieve this goal, the following is the challenge posed to science educators: "We need to help all our young people to be ready to engage with complex scientific and technological issues, some of which may not even be on the scientific agenda, and to make decisions about

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their use which pay due heed to their local culture. This implies that… a new teaching methodology is needed, designed to inspire a lifelong interest in science, and the ability to relate this to the community's way of living, with an understanding and respect for inherited values" (Jegede & Solomon, 1999, p.8).

Inspiring students' interest in science requires creativity and innovativeness on the part of educators. Although only a small percentage of students who take up introductory science end up pursuing a career in the sciences, it is important to instill in non-science majors an affinity for the sciences. Students pursuing a business degree or liberal arts studies eventually become leaders in government and industry. As future decision-makers in the social, political, and economic circles, these students hold the key towards making research and development in science and technology a primary component of the socio-economic cycle.

In the Philippines, the Commission on Higher Education mandates that all students pursuing a business or a liberal arts course take at least six (6) credit units of courses in the Natural Sciences. The six units could be a study of "Science, Technology, and Society", or an introductory (survey-type) course in Biology, Chemistry, or Physics.

Students' Pre-conceptions and Beliefs

The aim of every science teacher is to ensure that students understand and appreciate the material of the course. The University of Maryland Physics Education Research Group posits that what students expect will happen in their introductory college-level physics course plays a critical role in how they will respond to the course. These expectations affect what type of information students will listen to and will ignore in the "firehose of information provided during a typical course by professor, laboratory, and text" (Redish, Saul, & Steinberg, 1998). Students' understanding of what science is about and what goes on in a science class is a valuable input to the teaching-learning process. If we are to achieve our goal of increasing students' appreciation and understanding of science, we need to look at how our students view science and how we could use these initial conceptions to our advantage in our science classrooms.

The research conducted by David Hammer (1994) has shown how students' epistemological beliefs affect which activities students select in constructing their own knowledge base and in building their own understanding of the content of the course. Studies of student expectations in science in pre-college classrooms (Carey, Evans, Honda, Jay, & Unger, 1989; Songer & Linn, 1991) reveal that student attitudes towards their classroom activities and their beliefs about the nature of science and knowledge affect their learning. Studies that looked at general cognitive expectations of adult learners include the work done by Perry (1970) and Belenky, Clinchy, Goldberger, and Tarule (1986).

Redish et al. (1998) described the work done by Perry (1970) with Harvard and Radcliffe students throughout their college career and the longitudinal study done by the group of Belenky et al. (1986). Both studies found an evolution in the expectations of their subjects – moving through a "received knowledge" stage, in which students expected to learn the "truth" from authorities, to a sophisticated "consciously constructivist" stage, where the subjects accepted their own personal role in deciding what views were most likely to be productive and useful for them.

Research has shown that students bring with them their experiences of the world (Laws, 1997; Lawson, 1998; McDermott & Redish, 1999; van Domelen & van Heuvelen, 2002), which lead them to develop many concepts about how the world functions. These concepts oftentimes do not match with what they are supposed to learn in physics courses (Hestenes, Wells, & Swackhamer, 1992; Hestenes & Wells, 1992; Halloun & Hestenes, 1985; Maloney, O'Kuma, Hieggelke, & van Heuvelen, 2001). These pre-conceptions make it difficult for students to learn the material needed in their college-level physics course.

The study conducted by Boone (1997) looked at science attitudes of selected middle school students in the city of Shanghai, China. Analysis indicated that when the male and female Chinese students differ in their response patterns, females select the more intense response ("strongly agree" as opposed to "agree"; "strongly disagree" as opposed to "disagree"). The female students selected strongly agree / strongly disagree in much larger percentages than the male students (who tended to respond using the agree / disagree option). Furthermore, the female students often selected responses suggesting that they were more interested in the science topics and issues presented in the survey. A statistically significant difference among female / male responses was observed in the following sample survey items – "science films bore me to death", "I would like to join a science club that meets after school", "I like to make scientific drawings" – with the female students selecting the more pro-science responses than the male students.

Cognitive Expectations

It is not only physics concepts that students bring into the physics classroom. The University of Maryland Physics Education Research Group coined the term *cognitive expectations* to describe a student's set of attitudes, beliefs, and assumptions about what kind of things they will learn, what skills will be required, and what they will be expected to do. These cognitive expectations focus on students' understanding of the process of learning physics and the structure of physics knowledge rather than about the content of physics itself.

The Maryland Physics Expectations (MPEX) Survey is a 34-item Likert-style questionnaire (agree – neutral – disagree) developed by Edward Redish, Jeffrey Saul, and Richard Steinberg of the Department of Physics, University of Maryland. The MPEX survey is designed to probe students' expectations, attitudes, and beliefs about six aspects or dimensions of learning physics. A description of the development, validation, and calibration of the instrument may be found in the paper by Redish et al. (1998). The University of Maryland group proposed six dimensions along which students' beliefs toward the way of doing Physics could be categorized. The first three dimensions are taken from David Hammer's research on student's epistemological beliefs (Hammer, 1994). Building on the work done by Perry (1970) and Songer and Linn (1991), Hammer classified student beliefs regarding the nature of learning Physics into three categories: independence, coherence, and concepts. The University of Maryland Physics Education Research Group added three dimensions – reality link, math link, and effort link – to complete the six dimensions of learning physics being probed by the MPEX. The MPEX instrument is available in the web, http://www.physics.umd.edu/perg/expects/mpex.htm

Redish and Steinberg (1999) have reported that based on the results from more than 1,500 students from six American colleges and universities, it is clear that many students come into physics courses with unfavorable views about the nature of learning physics. More worrisome is that these views tend to deteriorate after a semester of university physics. However, it does appear that, in certain modified learning environments, student views do evolve to becoming more favorable. In the *Workshop Physics* classes that Redish and Steinberg (1999) observed, the students showed a 2.5 standard deviation improvement on the average of the independence, coherence, and concepts clusters of the MPEX.

Elby (2001) described the curricular reforms instituted in a small high school – the use of small groups during activities and problem solving, parts of which resemble *Tutorials in Introductory Physics* (McDermott, Shaffer, & the Physics Education Group, 1998) and *Real Time Physics* (Sokoloff, Thornton, & Laws, 1999) –which helped the students develop substantially sophisticated beliefs about knowledge and learning, as measured by the MPEX.

Working with Canadian college students, van Aalst and Key (2000) reported results obtained with the MPEX survey in: (a) a course for students who have not previously taken a second course in physics in high school; (b) physics for the life sciences; (c) honors physics; and (d) physics for engineers. Comparing the student responses with the "expert group" of Redish et al. (1998), the researchers found out that (i) over-all, agreement with experts decreased after two semesters of instruction, and (ii) there were significant differences between the response patterns for students in the first two courses compared with the last two (honors physics and physics for engineers).

As described in the study by Redish et al. (1998), the following dimensions of learning physics are probed by the MPEX:

Independence [beliefs about learning physics] The learner takes responsibility for constructing her/his own understanding (which involves an active process of reconstructing one's own understanding) or the learner takes what is given by authorities (teacher, textbook) without evaluation (simply receiving information).

Coherence [beliefs about the structure of physics knowledge] The learner believes physics needs to be considered as a connected consistent framework (a single coherent system) or the learner believes that parts of physics can be treated as unrelated facts or pieces (as a collection of isolated pieces).

Concepts [beliefs about the content of physics knowledge] The learner attempts to understand the underlying ideas and concepts or the learner focuses on memorizing and using formulas.

Reality Link [beliefs about the connection between physics and reality] The learner believes that ideas learned in physics are relevant and useful in a wide variety of real contexts or the learner believes that ideas learned in physics have little relation to experiences outside the classroom.

Math Link [beliefs about the role of mathematics in learning physics] The learner considers mathematics to be a convenient method of representing information about physical phenomena or the learner views physics

and math as independent subjects with little relationship between them (the mathematical formalism is just used to calculate numbers).

Effort Link [beliefs about the kind of activities and work necessary to make sense out of physics] The learner makes an effort to utilize available information and make sense out of it (they expect to think carefully and evaluate what they are doing based on available materials) or the learner does not attempt to use available information effectively.

Experimental Design

The present study describes to what extent student's *cognitive expectations* – expectations about the learning process and the structure of knowledge – change after going through an Introductory Physics course. Students' cognitive expectations were documented using the MPEX survey. The students were asked to take the MPEX as a pre-course survey during the first week of class, and again during the final exam week as a post-course survey.

The participants in this study (average age, 17 years old) include the following students of a private university in Manila, Philippines:

- One hundred twenty-one freshman Business majors enrolled in *Environmental Physics* during the second and third terms of school year 2005-2006, and
- One hundred and nineteen freshman Liberal Arts majors enrolled in *Introductory Physics for Liberal Arts Students* during the second and third terms of school year 2005-2006.

Both groups had about 50% male and 50% female respondents taking the MPEX.

The student's response for each item in the MPEX was compared with the "experts' response". During the development of the MPEX instrument, Redish et al. (1998) conducted consultations with lifelong learners (experienced physics instructors who have a high concern for educational issues and a high sensitivity to students) in order to develop the instrument's answer key. When a student's response to the survey item is in agreement with the response of the "expert group", the response is described as *favorable*, otherwise it is described as *unfavorable*.

Discussion of Results

Tables 1 and 2 show the summary of the students' agreement / disagreement with the expert response for the six dimensions (clusters) probed by the MPEX. Neutral responses are not presented in the data tables – the reader could determine these by adding the % favorable response and the % unfavorable response, then subtracting the result from one hundred.

Table 1. *The Percentage of Liberal Arts students whose response is the same as experts (favorable) and whose response differs from the experts (unfavorable).*

	% favorable		***% unfavorable***	
Dimension / Cluster	Pre-course	Post-course	Pre-course	Post-course
Independence	34.81	37.93	34.81	40.69
Coherence	27.41	26.21	43.70	49.66
Concepts	26.54	29.89	42.59	43.10
Reality Link	57.41	62.93	18.52	17.24
Math Link	41.36	37.93	32.10	36.78
Effort Link	61.48	65.52	14.81	13.79

Table 2. *The Percentage of Business majors whose response is the same as experts (favorable) and whose response differs from the experts (unfavorable).*

	% favorable		***% unfavorable***	
Dimension / Cluster	Pre-course	Post-course	Pre-course	Post-course
Independence	26.96	30.12	46.67	43.86
Coherence	22.32	28.67	48.41	43.86
Concepts	25.85	28.71	51.45	51.41
Reality Link	48.41	65.48	34.78	25.30
Math Link	36.35	51.75	39.61	26.75
Effort Link	51.88	59.04	20.00	13.49

Independence cluster

This cluster looks at how students think they acquire knowledge and develop their understanding of Physics. Do they acquire this knowledge and understanding from the instructor or can they develop it on their own? If students believe that they can develop an understanding of Physics independently, they are more likely to take responsibility for

their own learning. Perry (1970) notes that the more mature students understand that developing knowledge is a participatory process. As the learner matures, s/he takes responsibility for constructing knowledge.

The two groups of non-science major students who were surveyed for the present study posted a slight increase in their percentage favorable response for this cluster. At the beginning of the course, 34.8% of the responses of the Liberal Arts students and 26.9% of the responses of the Business majors were in agreement with the responses given by the expert group of Redish et al. (1998). By the end of their Introductory Physics course, the Liberal Arts students posted a 37.9% agreement with experts, while the Business majors reported a 30.12% agreement. Redish et al. (1998) note that a shift of 5% in students' responses is significant, thus taken as a whole, we do not see a significant improvement in this cluster.

Lifelong learners (the 'experts' in Redish et al.'s 1998 study) believe that students should disagree with MPEX item # 13, "My grade in this course is primarily determined by how familiar I am with the material. Insight or creativity has little to do with it". At the beginning of the trimester, only 26% of the Liberal Arts students who were surveyed gave a favorable response. By the end of the course, 38% of the students responded by saying that creativity is needed in order to learn Physics. The Business students rated relatively low in this cluster, as evidenced by the relatively low favorable responses generated for this particular question [pre-course favorable rating 19%; post-course rating, 21%].

Understanding equations in an intuitive sense, rather than taking them as givens [MPEX item # 8] exemplifies a certain level of independent learning. For this item, the Business students did not show any improvement in their agreement rating with the 'experts' [pre-course favorable rating and post-course rating, 33%].

For MPEX item # 17, "Only very few specially qualified people are capable of really understanding physics". In response, the experts say that they disagree with this statement. Initially, 45% of the Business students and 72% of the Liberal Arts students gave a favorable response – they thought that most people could understand Physics. By the end of the course, 53% of the Business students and 75% of the Liberal Arts students are in agreement with the experts.

Coherence cluster

Redish et al.'s (1998) experts believe quite strongly that students should see Physics as a coherent, consistent structure. Students who emphasize science as a collection of facts fail to see the integrity and coherence of the whole structure. For MPEX item # 12, "Knowledge in Physics consists of many pieces of information, each of which applies primarily to a specific question", 65% of the respondents agreed with this statement at the beginning of the course, which is contrary to the experts' response. By the end of their Introductory Physics class, a majority of the Business majors (63%) and the Liberal Arts majors (72%) still failed to see the connections between the different concepts they have learned.

The students' response on MPEX item # 29, "A significant problem in this course is being able to memorize all the information I need to know", reveal that up to the end of the course, 35% of the Business majors and 42% of the Liberal Arts majors focus on memory work, rather than attempting to find the relationships between concepts.

The post-course data gathered for the coherence cluster – Liberal Arts students, 26.2% favorable responses; Business majors, 28.7% favorable responses – could lead us to conclude that the students think that the knowledge they learned are simply pieces of information that are not related.

Concepts cluster

This cluster is intended to probe whether students are viewing the solving of Physics problems as simply a mathematical manipulation of an equation, or if instead, they are aware of the fundamental role played by Physics concepts in complex problem solving. For students who had high school Physics classes dominated by "simple problem solving" (find the right equation, then calculate a number), it is expected that mostly unfavorable responses will be found in this cluster. Learners who are aware of the fundamental role played by physics concepts in problem-solving view doing physics as more than the "substitute–the–givens–and–solve–mathematically" approach in high school physics.

The favorable shift in the students' responses to MPEX item # 4, "Problem solving in physics basically means matching problems with facts or equations and then substituting values to get a number" [Business majors: 10% to 19% favorable response (disagree)], and MPEX item # 26, "When I solve most exams or homework problems, I explicitly think about the concepts that underlie the problem" [Liberal Arts majors: 67% to 83% favorable response (agree); Business majors: 70% to 78% agreement with the experts] show that the students have taken a conscious effort in

learning the concepts. This result could partly be explained by the conceptual approach taken by the teachers who taught the course. As the two courses, Environmental Physics and Introductory Physics for Liberal Arts Students cater to non-science majors, the discussion focused more on the understanding of concepts, rather than the mathematical equations involved in learning Physics.

Reality Link cluster

Learners who believe that ideas learned in physics are relevant and useful in a wide variety of real contexts will give a high rating to this dimension. The items probe whether the students feel that their personal real-world experiences are relevant to the Physics course. The students who took the Introductory Physics course saw the link between the physics concepts and real-life experiences. The post-course survey generated 63% agreement with the experts for the Liberal Arts students and a 65% agreement for the Business majors. The examples given in class –medical applications (magnetic resonance imaging, ultrasound, ECG) and the environmental applications of the physics concepts learned –reinforced the link between the physics concepts and reality.

This cluster also looks at the likelihood a student will think about the reality of a solution to a given problem. The experience of Physics teachers leads us to posit that many students will make calculations and not even think about whether the answer makes sense. Redish, et al. (1998) presented, as an example, a student who does a calculation of the speed with which a high jumper leaves the ground and comes up with 8,000 m/s (as a result of recalling numbers with incorrect units and forgetting to take a square root) may not bother to evaluate that answer and see it as nonsense on the basis of personal experience.

Math Link cluster

An important component of a Physics course is the development of students' ability to use abstract and mathematical reasoning in describing and making predictions about the behavior of real physical systems. The responses in the math link cluster show that the Liberal Arts students who participated in the study have not yet seen the deeper physical relationships present in the equations [only 38% favorable responses].

The responses of the Business majors in the math link cluster [pre-course 36.4% agreement with experts; post-course 51.8% favorable responses] show that this group of students could see the deeper physical relationships present in the equations, rather than simply using math in a purely arithmetic sense.

Effort Link cluster

This cluster measures the willingness of students to put forth the effort necessary to make sense of topics in Physics. Two-thirds of the total number of Liberal Arts majors and 60% of the Business majors responded that the effort they exert in learning Physics is similar to the effort exerted by the life-long learners (experts) interviewed by Redish et al. (1998). The results reported in this study [a significant increase in the percentage of students giving a favorable response; Liberal Arts students, 61% to 66%; Business students, 52% to 60%] differ from the results obtained by Redish et al. (1998) in their original study where they found a downward shift in the effort the students exerted. Similar to what this present study obtained, Van Aalst and Key (2000) also reported a positive change in the effort cluster for the students they surveyed.

Synthesis

The students' responses reflected the highest levels of agreement with the 'experts' response' in the independence, math link, reality link, and effort link clusters of the Maryland Physics Expectations (MPEX) Survey. Student beliefs play an important role in student's understanding and appreciation of the Physics taught to them. The study has shown that it is possible to move students from a novice-like view of Physics towards an expert-like view. The students reported they were exerting the effort required of them that will allow them to understand Physics. They have likewise seen the value of learning the fundamental concepts in the study of Physics. A favorable shift in the responses of the Business majors was recorded in the math link cluster. The responses of the Liberal Arts students in the independence cluster reflect their openness to take responsibility for constructing their own knowledge. There is a need, though, to strengthen the integration between the various concepts learned, as reflected in the data obtained for the coherence cluster of the MPEX.

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